

REMARKS

Claims 1-7 are pending in the application. Claims 1-7 are rejected. Claims 1 and 4-6 are currently amended. Claims 3 and 7 are cancelled, and new claims 8-16 are added. No new matter is entered upon entry of these claims or amendments.

Claim 1 is amended to address the objections cited by the Examiner alleging indefiniteness, explicitly describing a process consistent with the term “tunability.” Additional commentary on this point is provided below. The amendments to claim 1 also incorporate the limitations of original claim 4, make explicit that the method applies to compositions of a given carbide, make explicit that the claim refers to “tuning” as part of the method and not some after-the-fact processing, and provides a quantitative measure for “narrow” pore size distribution. Support for this last feature is found in Figure 1. Additional support for this amendment is also found on page 7, lines 7-9 and Figure 2.

Claim 4 is amended to further specify a narrower temperature range used in the method of this invention. Support for this amendment is found in the specification *inter alia* in Figure 2.

Claim 5 is amended to further specify a narrower temperature range used in the method of this invention. Support for this amendment is found in the specification *inter alia* on page 6, lines 4-6, and on page 7, lines 21-22.

Claims 6 is amended and claim 9 is added to clarify the accuracy attribute of the present invention, as indicated by the deleted term “tunability.”. Support for this amendment is found in the specification *inter alia* on page 5, lines 22-23.

Claim 8 is added to further describe the ability of the present invention to maintain the narrow pore size distributions on changing temperatures. Support for this amendment is found in throughout the specification, *inter alia* in Figure 2.

Claim 10 is added to further describe the carbides which may be used in this invention. Support for this addition is found in the specification *inter alia* on page 4, lines 27-28

Claim 11 is added to further define chlorine as a halogen which may be used in this invention as chlorine. Support for this addition is found *inter alia* on page 4, lines 18-20.

Claims 12 and 13 are added to further describe the mean pore size and distributions of this invention, incorporating the definition of the physical size of nanopores as less than about 2 nanometers, as accepted as standard by those skilled in the art. That is, IUPAC defines nanopores (or micropores) as having mean pore diameters less than about 2 nm. Support for these additions are found in the specification *inter alia* in Figure 2.

Claim 14 is added to further specify a narrower range of nanopore size distributions than cited in claim 1. Support for this addition is found in the specification *inter alia* in Figure 2.

Claim 15 is added to further include the step of reacting at least one additional quantity of the carbide composition with the halogen at a temperature in the range of about 200°C to about 1400°C, to produce a nanoporous composition characterized as having a mean pore diameter that differs by less than about 0.2 nm than the mean pore diameter in the first quantity or the second quantity. Support for this addition is found in the specification *inter alia* in Figure 2.

Claim 16 is added to define a method for making a nanoporous carbon with a predetermined nanopore size. This method is implicit in the concept of tunability as used within the specification.

Before addressing the rejections and objections of the Examiner, it is appropriate to reiterate the invention made and described in this application. From his remarks, it appears that the Examiner considers the invention simply to be the ability to halogenate carbides so as to produce nanoporous carbon. Rather, the Applicants have discovered that, through careful selection and *control of processing temperatures, for a given carbide precursor*, it is possible to control and define the nanopore sizes and nanopore size distributions of the resulting carbon articles. While the art cited by the Examiner may disclose the use of chlorine to form porous carbide-derived carbon, even nanoporous carbide-derived carbon, until the discovery described in this invention, it was believed that subjecting a given carbide composition to halogenation at elevated temperatures would provide a limited series of discrete nanoporous compositions whose nanopore sizes varied by discrete “jumps” (or quanta), the distances of those “jumps” associated with the distance between graphitic layers; i.e., ca. 0.3-0.4 nm, such that the available pore sizes

for a given carbide composition was limited to a finite number of pore sizes by the nature of the original carbide composition.

As but one example, Federov (Mendeleev Chemistry Journal, 39 (6) pp. 87-87) describes the “chlorination of metal carbides at high temperatures is among the number of quite well-studied and assimilated processes in non-ferrous metallurgy and the chemical industry,” (page 88, line 3-4). Reporting on the range of work conducted at the Leningrad Institute of Technology during the period 1977-1992, which focused on the “[c]onditions of carbide chlorination . . . including a thermodynamic analysis of reactions and the experimental study of their kinetics as a function of such factors as temperature, reaction ratio, dispersion of carbides, and conditions of contact of carbide with chlorine,” describes *only* the impact of reaction ratio, dispersion of carbides, and conditions of contact of carbides with chlorine.

Similarly, Gordeev, *et al.* (WO 98/54111, page 7, line 26 through page 8, line 20) describes *inter alia* the prevailing thinking until the present Applicants’ invention:

Current notions of carbon material structure point out that nanopores generated during the thermochemical treatment process are formed by ordered or disordered graphite planes of carbon, which for simplicity might be considered as shaped slots, the width of the latter depending on the type of carbide used for forming of the workpiece with transport porosity.

The same reference goes on to describe a formula for determining **nanopore sizes which depend exclusively on the nature of the carbide precursor.**

The Applicants discovered that it is possible to provide compositions from a given carbide precursor with much smaller differences, so as to “de-limit” the number of mean pore sizes available from a given carbide composition. In this way, it is possible to “tune” the final compositions, and such is implicit in the use of this term “tunable.” The Applicants are unable to find any evidence that such nanopore “de-limited tuning” has been previously described by varying halogenation temperature, either explicitly cited or necessarily inherent in, or taught by any of the art cited by the Examiner.

Additionally, the Applicants are providing a listing of additional art in an Information Disclosure Statement to be considered by the Examiner, none of which appears to disclose or describe that by careful control of processing temperatures it is possible to control the nanopore

sizes of the resulting carbon articles, in the way or degree as described herein, despite the long-felt need of manufacturing nanoporous carbon to specific pore nanodimensions. Several of these references do show attempts to vary the resulting nanopore sizes by using *compositional variations* of the carbide precursors or by treating porous carbons bodies *post-halogenation* to achieve the same effects as described in this instant invention.

Further, as evidence of the novelty of this invention, the Applicants ask that the Examiner consider the fact that this invention has recently been recognized by R&D Magazine with the prestigious R&D 100 award, as one of the revolutionary technologies of 2009. A copy of the announcement is provided as “**Appendix A**” and is attached to this response for the Examiner’s reference.

I. Claim Rejections under 35 U.S.C. §112, second paragraph

Claims 1-7 stand rejected under 35 U.S.C. §112, second paragraph, as being allegedly indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention. More particularly, the Examiner characterizes the terms “desired” and “narrow” in claim 1 as “subjective and unclear,” and “tunable” as “unclear in that it implies that the pore structure of the carbon product can be changed after it is recovered. Further, the Examiner alleges that claim 6 implies that “some sort of guess work was made before the process began.”

The Applicants do not agree with these characterizations. The term “desired” is not subjective, as its common meaning at least implies, if not clearly indicates, that the skilled practitioner has a targeted pore size or pore size distribution envisioned before applying this, or any other method of control, and he or she “desires” to achieve that target. Nevertheless, the Applicants have amended claim 1 to eliminate this term.

Similarly, while the Applicants do not necessarily agree with the Examiner’s characterization of the phrase “tunable” as being unclear, this term has also been eliminated from claims 1 and 6. Instead, claim 1 is amended to provide a clear and explicit description of the concept of tunability as described in this invention.

Again, the Applicants do not necessarily agree that the term “narrow” is subjective or unclear in the context wherein it is used. Rather, the Applicants believe that it is clearly understood, and commonly used, by those skilled in the art, in the context of pore size distributions. Nevertheless, in an effort to advance prosecution, the Applicants have re-characterized “narrow” in terms of full width at half maximum, a term commonly used when referring to distribution curves. Support for the specific numerical characterization of this value is provided *inter alia* in Figure 1.

II. Claim Rejections under 35 U.S.C. § 102(b) – “Leis.”

Claims 1, 3-7 stand rejected under 35 U.S.C. §102(b), as being allegedly anticipated by Leis J., *et al.*, “Carbon nanostructures produced by chlorinating aluminum carbide,” *Carbon*, 2001, 39, 2043-2048 (hereinafter “Leis”). The Examiner remarks that “Leis teaches on pg. 2043 reacting AlC and halogen gas at 900C. The teaching of Ti, Si carbide is noted. No difference is seen in the carbon product.” Even if the Applicants were to agree that the Examiner is correct in his interpretation of the art, which they do not, they disagree with the characterization that this anticipates the claims of the instant invention which describe a method of selecting a specific pore size.

“A claim is anticipated only if each and every element as set forth in the claim is found, either expressly or inherently described, in a single prior art reference.” MPEP 2131. Moreover, “[t]he invention must be shown in as complete detail as is contained in the . . . claim.” *Id.* In addition, “[t]he elements must be arranged as required by the claim.” *Id.* *Leis* fails to teach every element of the claim, arranged as required by the claims, in the complete detail required under 35 U.S.C. § 102.

As described above, the fact that a single carbon product may or may not contain nanopores is not a distinguishing feature of this invention. *Leis* does not teach that articles can be produced by varying temperature, so as to yield mean differences in mean nanopore sizes of 0.2 nm or less. In fact, this reference provides an example of the thinking that a given carbide composition will yield nano-porous carbide-derived compositions whose mean pore diameters

differ by the approximate thickness of a graphitic layer, i.e., ca. 0.3 nm. Applicants note that three of the authors on the article cited by the Examiner were co-applicants on a patent application (WO 2004/094307) in which they described the ability to define nanopore size from halogenating carbides as exclusively defined by the composition of the initial carbide (page 6, lines 13-29). Similarly, Leis *et al.*, co-applied for yet another patent in this area (WO 2005/118471), and for the first time, acknowledged that “the peak pore size [can] be adjusted within a few angstroms by changing the carbide chlorination temperature,” citing the present Applicants’ work (page 1, lines 23-25).

Applicants respectfully request the Examiner to withdraw this rejection.

III. Claim Rejections under 35 U.S.C. § 103(a) – “Leis” taken with “El-Raghy.”

Claims 1-7 stand rejected under 35 U.S.C. §103(a), as being allegedly unpatentable over Leis J., *et al.*, *Carbon*, 2001, 39, 2043-2048 (hereinafter “Leis”), taken with El-Raghy, *et al.*, *J. Appl. Phys.*, 1998, 83(1): 112-119 (hereinafter “El-Raghy”). Specifically, the Examiner remarks on page 2, lines 28-30:

Leis does not teach the compound of claim 2. El-Raghy teaches it as a composite of TiC and SiC. Using it as a source is an obvious expedient to make the desired carbon, noting that Leis teaches carbide as useful materials in the introduction.

Applicants disagree with this characterization. Again, the fact that a single carbon product may or may not contain nanopores is not a distinguishing feature of this invention. The instant claims teach a novel method of producing carbide-derived carbon articles whose mean pore sizes can be made to differ by less than 0.2 nm.

To establish a *prima facie* case of obviousness, three basic criteria must be met. First, there must be some suggestion or motivation, either in the reference itself or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings. Second, there must be a reasonable expectation of success. Finally, the prior art reference must teach or suggest all the claim limitations. The teaching or suggestion to make the claimed combination and the reasonable expectation of success must both be found in

the prior art, and not based on Applicants' disclosure. MPEP § 2143, *In re Vaeck*, 947 F.2d 488, 20 USPQ2d 1438.

Applicants submit that the Office Action does not set forth any of these requirements. Neither *Leis* nor *El-Raghy* describes or teaches that nanopore size or pore size distribution can be controlled to this level by controlling the temperature. As described in the previous section, it was not even recognized that nanopore size could be adjusted by chlorination temperature until after publication of the present Applicants' work. This alone would belie the requirement that there would be a reasonable expectation of success. The existence of the compositions described in *El-Raghy* does not overcome this deficiency.

Applicants request reconsideration and withdrawal of the rejection

IV. Claim Rejections under 35 U.S.C. § 102(b) – “Boehm”.

Claims 1, 3, 4, 6, 7 stand rejected under 35 U.S.C. §102(b), as being allegedly anticipated by *Boehm*, *et al.*, Proc. 12th Biennial Conf. on Carbon, 1975, pp. 149-150 (hereinafter “*Boehm*”). Specifically, the Examiner remarks that “[p]age 149 teaches narrow-pore distribution carbon made from reacting TaC with [sic] at 500C.” Even if the Applicants were to agree that *Boehm* teaches a narrow-pore distribution carbon *composition* made from reacting TaC, they disagree with the characterization that this anticipates the claims of the instant invention which describe a *method* of selecting a specific pore size, or controlling it to within 0.2 nm or less. In fact, when discussing the effect of temperature, *Boehm* appears only to describe results in terms of pore volume, and correlating it with a thermodynamic maximum. As with *Leis*, *Boehm* provides no teaching that careful control of temperature can be used to control pore size or distribution to within 0.2 nm.

Accordingly, Applicants request reconsideration and withdrawal of the rejection.

V. Claim Rejections under 35 U.S.C. § 102(b) – “Federov”.

Claims 1, 3-7 stand rejected under 35 U.S.C. §102(b), as being allegedly anticipated by Federov, N.F., Mendeleev Chemistry Journal, 1995, 39(6): 87-97 (hereinafter “Federov”).

Specifically, the Examiner remarks that “[p]age 89 teaches making carbon from carbides at 800-1200C. The variety of materials is noted.” Even if the Applicants were to agree that Federov teaches making carbon *compositions* from carbides, they disagree with the characterization that this anticipates the claims of the instant invention which describe a *method of tuning* nanopore size with temperature. One of the several advantages of the present invention is that the pore size and distribution of a nanoporous carbon can be defined and controlled *for a given carbide composition*. As described above, Federov teaches that pore sizes can be varied by varying the composition of the starting carbide material. This is a different method than described by the instant invention, and in fact reinforces the statement that varying the temperature to achieve this level of control, which is arguably a simpler solution than producing carbide precursors of varying stoichiometries, was not recognized as a viable method prior to the instant invention.

Again, Applicants request reconsideration and withdrawal of the rejection.

VI. Claim Rejections under 35 U.S.C. § 103(a) – “Federov” taken with “El-Raghy.”

Claims 1-7 stand rejected under 35 U.S.C. §103(a), as being allegedly unpatentable over Federov, N.F., Mendeleev Chemistry Journal, 1995, 39(6): 87-97 (hereinafter “Federov”), taken with El-Raghy, *et al.*, *J. Appl. Phys.*, 1998, 83(1): 112-119 (hereinafter “El-Raghy”).

Specifically, the Examiner remarks on page 3, lines 8-10 of the outstanding office action:

Federov does not teach the compound of claim 2. El-Raghy teaches it as a composite of TiC and SiC. Using it as a source is an obvious expedient to make the desired carbon, noting the teaching of various carbides as useful materials and the opening page of Federov.

Applicants disagree with this characterization, for the reasons described above. That is, neither reference teaches or discloses a method of controlling pore size or pore size distribution

by deliberate control of process temperature, *to the degree described herein*. The fact that *El-Raghy* teaches the existence of a composite of TiC and SiC does not overcome the deficiency of the *Federov* reference.

VII. Claim Rejections under 35 U.S.C. § 102(b) – “Gordeev”.

Claims 1, 3-7 stand rejected under 35 U.S.C. §102(b), as being allegedly anticipated by *Gordeev*, *et al.*, Physics of the Solid State, 2000, 42(12): 2314-2317 (hereinafter “*Gordeev*”). Specifically, the Examiner remarks on page 3, line 13, “[p]age 2245 teaches chlorination of carbides such as Ti, Si.” While Applicants agree that *Gordeev* teaches chlorination of carbides, they disagree with the characterization that this anticipates the claims of the instant invention which describe a method of changing nanopore size by increments less than 0.2 nm *by temperature alone*. A careful reading of *Gordeev et al.*, reinforces the previously presented interpretation of the understanding in the prior art when it recites, “*Federov et al.*, revealed that *the* pore size in the carbon material prepared from SiC is equal to 0.8 nm. . .” (emphasis added) Implicit in this description is that SiC inherently produced this particular nanopore size. However, according to the present invention, it is also possible to produce nanoporous carbon from SiC which differs from this single value.

A claim is anticipated only if each and every element set forth in the claim is found, either expressly or inherently, in a single prior art reference. *Verdegaal Bros. v. Union Oil Co. of Calif.*, 814 F.2d 628, 631 (Fed. Cir. 1987); MPEP § 2131. The identical invention must be shown in as complete detail as is contained in the claim. *Richardson v. Suzuki Motor Co.*, 868 F.2d 1226, 1236 (Fed. Cir. 1989); MPEP § 2131. Clearly, the *Gordeev* reference does not teach that temperature alone can be used to modulate pore sizes in increments of less than 0.2 nm, and as such does not anticipate.

Applicants respectfully request that this rejection be withdrawn.

VIII. Claim Rejections under 35 U.S.C. § 102(b) – “Erickson”.

Claims 1, 3, 4, 6, 7 stand rejected under 35 U.S.C. §102(b), as being allegedly anticipated by Eriksson, *et al.*, U.S. Patent No. 4,454,013 (hereinafter “Eriksson”). Specifically, the Examiner remarks that: “[t]he reference teaches in the figure and col. 4 chlorinating Ti carbide to make carbon. No difference is seen in the carbon, Due [sic] to the similarity of the process.” Applicants disagree with this characterization.

Again, the fact that a single carbon product may or may not contain nanopores is not a distinguishing feature of this invention. The instant claims teach a novel *method of controlling* the nanopore sizes in carbide-derived carbon to within 0.2 nm by temperature alone. Nowhere in Eriksson is it even suggested that pore sizes can be selected or controlled to this level, nor does Erickson describe the deliberate control of temperature as a means for achieving this end. Applicants request reconsideration and withdrawal of the rejection

IX. Objection to describing Si as a metal.

Lastly, the Examiner remarks in the last 3 lines of page 3 that:

It is noted that Si is not a metal, and thus silicon carbide is excluded from the claims. If applicants disagree, then they are instructed to state so positively on the record, provide evidence that this is so and to amend the claims accordingly.

Applicants disagree with this characterization, but in an attempt to advance prosecution, have amended claim 1 to eliminate reference to “extracting metal.” Boron and silicon are generally considered metalloids, and are exemplified in the specification which supports this change (support for these carbides are previously presented). Applicants believe this change moots the objection and ask that it be withdrawn.

For all of the foregoing reasons, Applicants submit that the pending rejections should be reconsidered and withdrawn. Accordingly, Applicants submit that all pending claims are in condition for allowance and earnestly solicit the Examiner to allow the application on the existing claims. Should the Examiner desire any additional information, he is invited to call the undersigned attorney at the number listed below.

Date: September 9, 2009

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Attachment: "Appendix A"

“APPENDIX A”

Available from <http://www.rdmag.com/RD100-Awards-Nanoscale-Pore-Size-Control/>

Nanoscale pore size control supercharges versatile carbon

Porous carbon (commonly known as activated carbon or charcoal) has been known for over 3,000 years and is regarded as the most versatile porous material, not only because of the wide variety of structures that carbon offers but also because of the sheer variety of applications, ranging from gas storage to molecular sieves, catalyst supports, absorbents, electrodes in batteries, supercapacitors and capacitive desalination. The performance of all of these technologies depends heavily on pore size, and, until the recent arrival of **Tunable Nanoporous Carbon**, no manufacturing methods were able to provide the control of the pore size. Starting with an inorganic precursor, such as silicon carbide, materials scientists at Y-Carbon, Inc., King of Prussia, Pa., and Drexel Univ., Philadelphia, Pa., etched the metal or metalloid from the carbide in a halogen environment, such as chlorine, at elevated temperature. In this process, as metal is extracted layer-by-layer from the rigid metal carbide lattice, atomic-level control of porosity is possible. As pore formation in this process is due to removal of metal as a gaseous metal chloride, the carbon material contains open and accessible pores. The transformation of metal carbide to carbon is conformal and, because of conservation of shape and size in this process, carbon atoms are slightly relocated from their original positions during treatment, creating a porous carbon network. The development has shown that pore size control can be achieved in sub-Ångström (0.5 to 2.2 nm range) and sub-nanometer (3 to 30 nm range) accuracy by selecting the precursor material (titanium carbide, silicon carbide, etc.) and the synthesis conditions (temperature, time, etc.).